1039

Bulletin No. 131 April, 1912

FOUR NEW FUNGOUS DISEASES IN IOWA

By.
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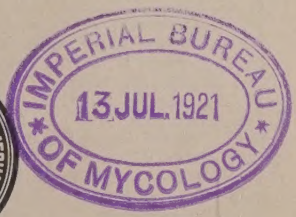
AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND THE MECHANIC ARTS

BOTANICAL SECTION



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FOUR NEW FUNGOUS DISEASES IN IOWA

BY

L. H. PAMMEL AND CHARLOTTE M. KING

During the past two seasons several important destructive fungous diseases of cultivated plants have made their appearance in Iowa, namely:

Timothy rust, alfalfa rust, apple canker, and onion smut.

About the middle of July, 1910, there was an abundance of timothy rust in a meadow in the vicinity of Ames; subsequently it was reported from other localities in the state. It was again noticed after the September rains in 1911, especially in the timothy breeding plots.

Somewhat earlier in 1910, H. S. Coe found alfalfa rust on alfalfa, also in the vicinity of Ames, and in 1911 near Altoona. It was abundant the past season in September on alfalfa in the breeding plots. It was first observed on isolated plants along the line of the C. & N. W. R. R., from which it spread to the plants along the right of way of the Ft. Dodge, Des Moines & Southern R. R., which runs through the college farm; from this tract it spread to an adjacent field and then to other alfalfa plots, where it reappeared after the fall rains of 1911.

During the winter of 1910, H. A. Simon and Sons of Hamburg, Iowa, called our attention to a serious canker disease of the apple in southwestern Iowa, and G. R. Bliss reported it from other sections of western Iowa. This proved to be the Illinois canker.

Onion smut was reported to us from Scott county, by Leslie Hird; subsequently F. F. Schutter of Pleasant Valley sent us a quantity of the diseased onions from his fields. A personal investigation of the disease in Scott county was made during the latter part of July, 1911. It was found as reported, a most serious disease.

TIMOTHY RUST, (*Puccinia phlei-pratensis* Eriks. & Henn.)

Timothy rust has been known for a considerable length of time, especially in Europe, where it is usually referred to common grass rust (*Puccinia graminis*) occurring upon many different host plants. Eriksson and Henning [1] gave the rust the name of *Puccinia phlei-pratensis*, believing it to be distinct, but Kern referred it to *P. poculiformis graminis*, considering it only a form of the common grass rust, or a so-called physiological species.

The history of timothy rust in this country is rather limited. A brief account of it is given in a paper by E. C. Johnson,[2]

"Timothy Rust in the United States," from its first appearance in 1882 as reported by Trelease.[3] Johnson thinks there may be some doubt about the determination of the host, referred to by Trelease, since only one leaf is preserved in the herbarium of the Missouri botanical garden. The specimen is ticketed "Pammel." There is no doubt about the specimen, since it was collected in the grass plots of the Wisconsin Agricultural Experiment Station.*

Subsequently in 1891, Wilson, Kent and Curtiss,[4] reported rust on timothy in Iowa. Johnson takes it for granted that the rust referred to by them was timothy rust. In looking through the Iowa State College herbarium we failed to find a rust on timothy bearing that date. The term used by the writers above referred to does not necessarily refer to what botanists understand by rust. The term was then popularly applied to a disease of timothy in which the conspicuous characters were the turning rusty brown of timothy leaves, due to an entirely different cause. This disease is much older than the first recorded appearance of real timothy rust in the United States, and it was common in Wisconsin in 1880, where also, the name of "rust" was applied to it. In this connection the statement was made by Pammel in 1899: "Timothy, so far as the writer knows, is not affected with any rust in the state of Iowa."[5] And in an address delivered before the Iowa Improved Stock Breeder's association in 1891, the statement was made that *P. graminis* does not occur upon timothy. This evidence indicates that this rust did not occur in the state at these earlier dates. So far as we know the first occurrence of the disease in Iowa was not until the summer of 1910.

Johnson first found the rust on timothy in the breeding plots in the Arlington Experiment station farm near Washington, in 1906. The epidemic was particularly severe. W. J. Morse, in 1908, made a brief unpublished report on the severity of the disease in 1907, the first evidence of rust appearing on the new growth about March 15. Experiments made in the extensive breeding plots of the United States Department of Agriculture indicated that there was considerable degree of resistance with the individuals of some varieties. Johnson in his recent paper reports it from New York, Virginia, West Virginia, and Ontario, Canada, in 1907. In 1908 it was wide spread in New York, Pennsylvania, and Virginia. In 1909 it was reported from Indiana, Kentucky, and Maine; in 1910 from Michigan, Minne-

* The writer recalls collecting rusts while a student and that in these grass plots there were several other grasses under cultivation, among them Meadow Foxtail and Tall Meadow Oat-grass, but no Red Top, which is very common in Wisconsin, Iowa, and Minnesota, and is frequently attacked by *Puccinia graminis*, not only on stem and sheath, but on the blades as well. The leaf of Red Top is very different in character from that of timothy and cannot be mistaken for it. I am firmly convinced that there was no doubt about the determination of the host plant by me in 1882.—L. H. Pammel,

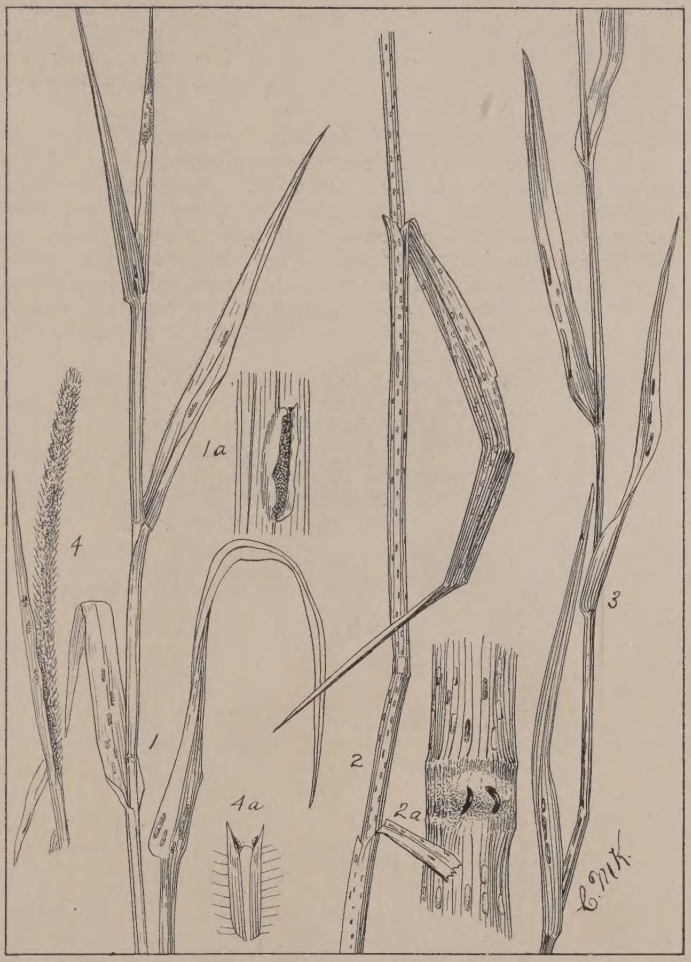

Fig. 1. TIMOTHY RUST, *Puccinia phlei-pratensis.*
1. Initial stage in field, 1a, sorus.
2. Advanced stage, 2a, sorus.
3. Plant infected through inoculation in greenhouse.
4. Timothy head affected by rust; 4a, rust on glume. (C. M. King).

sota, and Iowa. Kern recorded a number of additional localities for this rust in the east, and Selby reported it for Ohio. In a letter to the writer it was recorded for South Dakota by Olive, and Bakke found it in Missouri. In 1911 it was epidemic, appearing in central Iowa after the fall rains, there having been no evidence of it before September 1.

CHARACTERS OF THE FUNGUS

The uredo sori of timothy rust are roundish or elongated, and may be found on both sides of leaf, sheath, stem, and spike; those on the stem are longer, becoming confluent, and forming irregular areas. The uredo spores are spherical or subspherical, minutely echinulate, length 24μ-32μ, width 18μ-20μ. These spores germinate readily in sterilized water, or in weak solution of sugar.

For the purpose of comparing the uredo spores from timothy and oats, collections of rust from these hosts were made in the field, November 3, 1911.

Twenty-five representative uredo spores of *P. graminis* averaged 22μ by 33μ; twenty-five uredo spores of *P. phlei-pratensis* averaged 18μ by 27μ, being distinctly smaller than the former. The uredo spores of *P. phlei-pratensis* were also more elongate, and slightly darker in color. In shape the timothy spores vary from round to elliptical, and when placed in water for germination, they have a tendency to form a flocculent mass.

Measurements of uredo spores of oat stem rust. Nov. 3, 1911.
Mature and vigorous
18μ x 34μ
20μ x 24μ
20μ x 28μ
20μ x 32μ
20μ x 32μ
20μ x 32μ
20μ x 32μ
20μ x 34μ
20μ x 36μ
20μ x 36μ
20μ x 36μ
20μ x 38μ
20μ x 40μ
22μ x 30μ
22μ x 32μ
22μ x 32μ
22μ x 32μ
22μ x 38μ
24μ x 28μ
24μ x 32μ
24μ x 32μ
24μ x 32μ
24μ x 36μ
24μ x 36μ
24μ x 10μ
Average width 22μ
Average length 33μ

Measurements of uredo spores of timothy rust. Nov. 3, 1911.
Mature and vigorous
16μ x 22μ
16μ x 24μ
16μ x 28μ
18μ x 22μ
18μ x 24μ
18μ x 24μ
18μ x 24μ
18μ x 26μ
18μ x 28μ
18μ x 28μ
18μ x 28μ
20μ x 20μ
20μ x 24μ
20μ x 24μ
20μ x 24μ
20μ x 24μ
20μ x 24μ
20μ x 24μ
20μ x 24μ
20μ x 24μ
20μ x 26μ
20μ x 28μ
20μ x 28μ
20μ x 28μ
20μ x 28μ
Average width 18μ
Average length 27μ

GERMINATION OF RUST SPORES OF TIMOTHY

Freshly collected uredo spores, placed under observation on the morning of October 4, 1911, had germinated by the morning of October 5. No frost up to that date.

Timothy rust gathered later in a sleet storm did not germinate in water, in sugar solution, nor upon leaves of either old or young plants in the greenhouse. Many spores showed an exhausted appearance. The rust was generally affected by a parasitic fungus.

Teleutospores form in the same sori as uredo spores or in separate sori. The sori are elongated and are found along veins

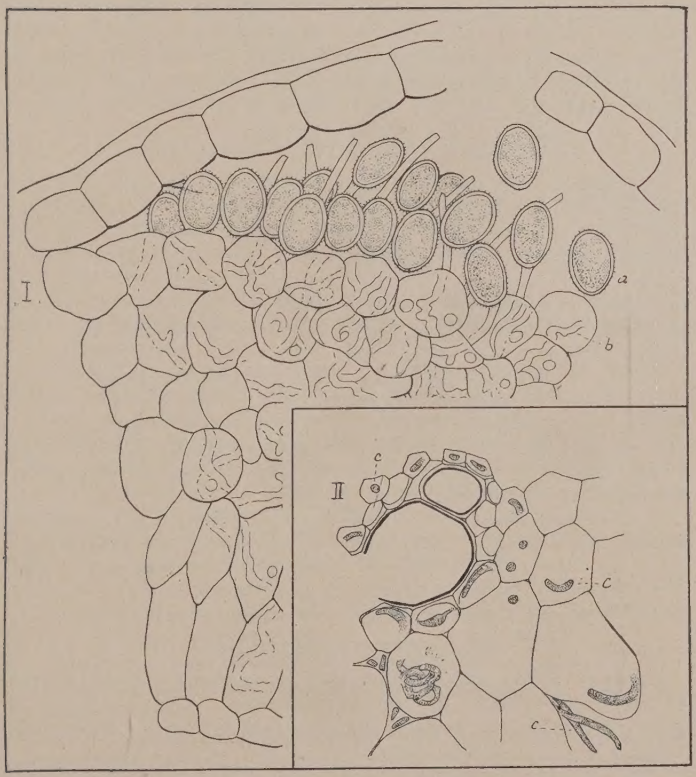

Fig. 2. SORUS OF PUCCINIA PHLEI-PRATENSIS.
I. Uredo spores; a, uredo spore; b, hypha.
II. Section of cell of leaf, showing mycelium of fungus; c, portions of hyphae. (Sketch II, from preparation made by Prof. J. Martin).

of leaf or stem, frequently clustered, persistent, open, as in *P. graminis*. The spores are 2-celled, brownish, fusiform, smooth; constricted at the middle, the upper cell rounded; pedicel long, persistent, yellowish brown. Length, 38-52μ, width, 14-16μ. These cells are inclined to be narrower than typical *P. graminis*, and, as in the case of that fungus, are very variable.

THE AECIDIUM STAGE

Eriksson and Henning do not connect this fungus with an aecidium or cluster cup stage. These writers made a large number of inoculation experiments upon barberry but without positive results except a feeble infection in one case. Arthur,[6] who reported on cultures of Uredineae in 1900 and 1901, says that *Puccinia poculiformis* from reed grass produces aecidia upon common barberry. Eriksson surmises that the aecidium stage of this rust has dropped out as a part of the life cycle of the fungus. No aecidium was observed on barberry about Ames in 1910 or 1911.

THE RELATION TO OTHER HOST PLANTS

The timothy rust has been reported by Dr. Eriksson and by Dr. Lindau upon fescue and timothy grasses. There is the possibility that this is only a form of the common grass rust. According to Johnson timothy rust transfers readily to *Avena sativa, Secale cereale, Festuca elatior, Dactylis glomerata, Arrhenatherum elatius* and *Poa compressa*; negative results were obtained on wheat and barley. Our own inoculation experiments indicate that it is transmitted to a few other host plants of the grass family. It certainly did not spread rapidly in the greenhouse. And while orchard grass was observed diseased with *Puccinia graminis* in the field a little distance from the timothy one could not say that infection came from timothy. Red top was abundantly infected with *P. graminis* at the time when timothy rust was spreading rapidly among adjacent plants of timothy.

P. phlei-pratensis is not the only rust found upon timothy; during the summer of 1910 a rust * was found (by Miss King) upon the leaves of timothy which was growing adjacent to wild rye (*Elymus robustus*), which was abundantly affected by *Puccinia Impatientis*, and which this rust closely resembled.

INOCULATION EXPERIMENTS

Johnson [7] made a large number of inoculations of uredo spores of timothy rust upon the following grasses: *Triticum vulgare, Avena sativa, Secale cereale, Festuca elatior, Dactylis glomerata,*

* Rust of Timothy (*Puccinia Impatientis*) (Schw.) Arth. Uredo sori small, linear, numerous and scattered along the veins of the lower surface of leaf, and sheath; teleuto-sori linear along veins of leaf covered by epidermis but distinctly raised. Teleutospores surrounded by paraphyses; oblong or elongate, cuneate, but slightly constricted; pedicel short; spores light except at apex. Top of upper cell slightly irregular occasionally with two slight points at extremities. Spores variable in width, 9-13. 5μ to 28-40μ.

Arrhenatherum elatius, Poa compressa, Poa pratensis, Elymus virginicus, E. canadensis, E. robustus, Agropyron Smithii, Hordeum jubatum, Phalaris arundinacea, Holcus lanatus, Asprella Hystrix, Agrostis alba, and *Bromus unioloides.*

He also inoculated timothy with uredo spores from the following hosts, *Triticum vulgare, Avena sativa.* He succeeded, as has been said, in obtaining quite readily positive infection results with *Puccinia phlei-pratensis* on the following hosts: oats, rye, fescue grass, orchard grass, Canadian blue-grass, and tall meadow oat grass, but was unsuccessful with three species of wild rye (*Elymus canadensis, E. virginicus,* and *E. robustus*), western wheat grass, squirrel tail (*Hordeum jubatum*), and reed-grass (*Phalaris arundinacea*), velvet grass, *Asprella Hystrix,* red top, and Shrader's Brome.

In the fall of 1910 about fifty plants (several hundred leaves) of timothy were inoculated by sprinkling upon them water containing uredo spores of timothy rust. After a lapse of five days, uredo pustules made their appearance. In addition a large number of experiments was made with other grasses, foxtail (*Setaria glauca*), Barnyard grass (*Echinochloa crusgalli*), blue grass (*Poa pratensis*), barley (*Hordeum vulgare*), brome grass (*Bromus inermis*), wheat (*Triticum vulgare*), and red top (*Agrostis alba*). In none of these cases was infection produced except in oats (*Avena sativa*).

During the fall of 1911 inoculation experiments were carried on with timothy, English rye, other grasses, and oats, grown in the greenhouse.

Inoculations were as follows: on Oct. 3, 1911, three pots of young timothy plants, on the first leaf; pot with 200 young plants, inoculated with timothy rust; pot with 500 young plants, with timothy rust; pot with 200 young plants with red top rust. The method of procedure was as follows: a quantity of spores, placed in about 2½ c.c. of water, was distributed over the plants; the plants were then protected by bell-jars for 48 hours.

On Oct. 9, no rust pustules were observed; inoculations were repeated upon the three pots of timothy plants.

On Oct. 9, young seedling plants of the following grasses were inoculated with timothy rust: wheat, oats, barley, English rye-grass, Italian rye-grass, timothy, red top, meadow fescue.

On Oct. 18, rust pustules were observed as follows: on English rye 2 sori, from timothy rust inoculation; on timothy 2 sori from timothy rust.

On Oct. 23, English rye showed 3 sori from timothy rust; timothy showed 3 sori from timothy rust.

On Oct. 23, timothy showed 1 sorus from stem rust of oats, inoculated Oct. 18.

It is evident from these results that conditions were not pres-

ent in the greenhouse to induce rust upon any of the plants except timothy and oats; it is difficult to account for the sudden appearance of timothy rust in the field unless it was conveyed from some other host plants, because the disease was not observed here in 1909 or previous to the middle of July, 1910. Red top was abundant everywhere in proximity to the timothy, and it was abundantly rusted. It is probable, therefore, when the conditions are favorable, that timothy rust will appear in epidemic form after having been in some way transferred from related host plants.

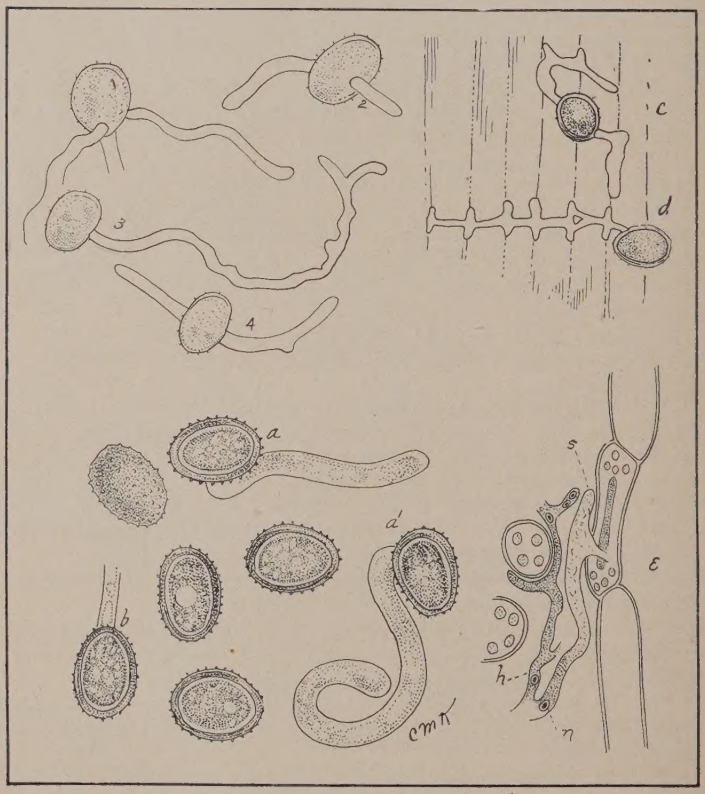

Fig. 3. GERMINATING SPORES OF TIMOTHY RUST
1, 2, at three hours in water; 3, 4, at 18 hours in water; a, a¹, germinating spores; b, spore with pedicel; c, d, spores sending germ-tubes across the surface of leaf; e, (after Evans) manner of entrance of germ tube by means of stoma; s, stomatal vesicle; h, hypha; n, nucleus.

In view of observations herein recorded, we conclude that timothy rust is only a form of common grass rust (*Puccinia graminis*); and that timothy has become susceptible to its attacks. It is in this respect not unlike the apple rust (*Rostelia pyrata*) upon the Wealthy apple, which, although long known in this state upon the wild crab apple, appeared in epidemic form on the Wealthy in 1905.

SPREAD OF THE FUNGUS

It is evident from the work of Eriksson and Henning that the mycelium is perennial in the tissues of the host plant, since they found the uredo stage very early in the season.*

The recent interesting work of Pritchard [7a] on the wheat rust, showing that infection may be carried through the pericarp of the seed, might be sufficient to account for the spread of the disease during the summer and fall.

METHODS OF INFECTION

There are two methods of infection for rusts. The germ-tube may enter the host by making its way through the cuticle and cell-wall of the host; this is the usual mode of penetration for the sporidia which develop from the teleutospores. On the other hand, germ-tubes produced by the uredospore and aecidio spores, as shown by DeBary, enter by way of the opening of the stoma.

Bolley [8] states of grass rust that the uredo spore sends out a filament which "bores its way into the stem or leaf." Olive [9] says that the sporidia from the teleutospores of grass-rust "grow down into the tissues" of the barberry; the aecidio spores "grow down through the breathing pores of the host plant;" the uredo spore, after germinating in the film of moisture on the plant, "grows down into the living tissues of the host."

However, Evans,[10] who has recently made a very detailed study of the cereal rusts, finds that in general two germ-tubes appear at first, but one quickly gets ahead of the other and arrests its growth. The germ-tube, as soon as it reaches a stoma swells, and forms the appressorium, from which a narrow branch passes through the opening of the stoma. As soon as the neck has entered the aperture, it enlarges to form the sole stomatal vesicle, which applies itself closely to the inner face of the stoma. The whole contents of the spore are poured into this vesicle. The germ-tube and appressorium quickly wither. Evans finds it characteristic of this species, that the hypha does not cling to the head of the guard cell. The nuclei are usually small, and oval in shape. The hyphae are uniform in size producing haustoria, delicate structures, which are somewhat variable in shape but

* In this connection the paper by Olive may be consulted.

Fig. 4. Rust upon timothy, *P. Impatientis*, teleutospores.

attain their greatest development in the cells bordering on the fibro-vascular bundle, which they are often branched.

In our study germination occurred readily in sterilized tap water. The uredo spores when placed on a leaf of timothy or fescue grass germinated readily; two tubes were usually put out, one of which developed more rapidly than the other, extending over the surface of the leaf until a stoma was reached through which the tube made entrance into the tissues of the host. It was observed, in a number of instances, that the germ tube made swellings at the cell-walls on the surface. As it advanced from cell to cell, it left successive enlargements, but penetration could not be observed at these swellings.

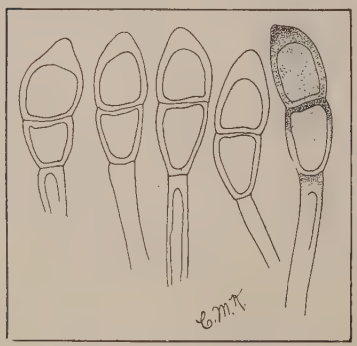

Fig. 5. *Puccinia phlei-pratensis*, teleutospores.

PARASITES UPON THE RUST

Timothy rust became badly infected with a parasitic fungus (*Darluca filum*) so that it became difficult to find uredo-so that were not infected; in comparatively few cases did the teleutospores develop until very late in the season.

ALFALFA RUST (*Uromyces striatus* Schroeter)

Fig. 6. Alfalfa rust, *Uromyces striatus*. Uredo stage.

During the month of July, 1910, H. S. Coe found on the right of way of the Fort Dodge, Des Moines and Southern railroad, some rusted plants in an isolated patch of alfalfa, about three-quarters of a mile east of an experimental plot of alfalfa on the college farm. In the course of two weeks the disease spread to other isolated patches about one-half mile west; and during early

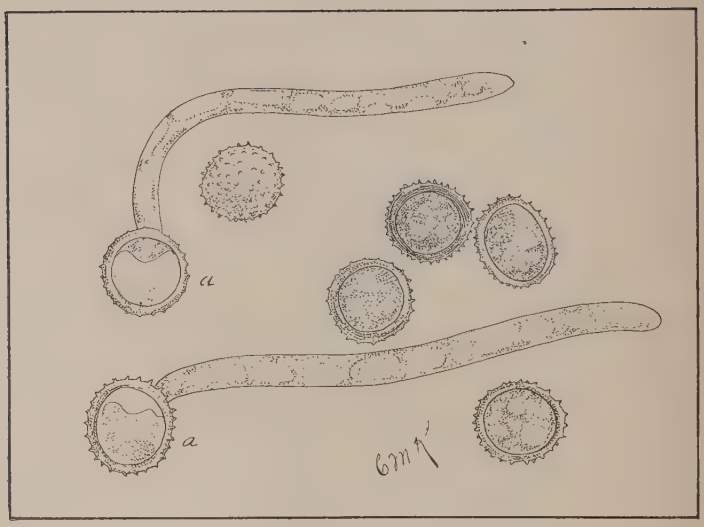

Fig. 7. Uredo spores of Alfalfa rust, *Uromyces striatus*; a, germinating spores.

August the rust was abundant on young alfalfa plants in the east experimental alfalfa plots. In September it was abundant on experimental alfalfa plots three-quarters of a mile west and north of the east experimental plots. There was no alfalfa between the east field and west field on the college farm, so that the spores were carried by the wind.

In the late summer of 1911, Mr. Coe observed the rust abundant near Altoona, Iowa; it also became again epidemic in the alfalfa plots of the college farm, and especially upon volunteer plants.

Fig. 8. Teleutospores of *Uromyces striatus*.

The plots of alfalfa in the experimental grounds were examined for the purpose of noting to what extent rust prevailed among them. A plot described as composed of "selected strong plants," unnamed, with nearly white flowers, was badly rusted; the adjoining plot, described as a recent "introduction from

Germany" (variety name not given) was sparsely affected by rust. The bush alfalfa (name not given) was not affected by the rust. The trailing alfalfa, while not rusted, was generally affected by spot disease. It was not found on the sweet clovers, *Melilotus alba*, and *M. officinalis*, growing in the proximity of the rusted alfalfa plants.

The alfalfa rust has been known in Europe for some time. It was described by Schroeter.[11] It is recorded by Lindau [12] for Germany, Saccardo [13] for Italy, Austria, Switzerland, Germany, and France. Selby [14] states it may scarcely have appeared in Ohio." Through the kindness of J. C. Arthur it has been possible to examine some material collected by Guy West Wilson on alfalfa in Indiana in 1907. The rust was common on *Medicago falcata* and Grimm's alfalfa, according to E. W. Olive. Alfalfa rust is reported by Heald and Wolf [14a] as present but not as the cause of serious damage. Letters were sent to various station botanists in regard to the disease, especially to western and southern states where alfalfa is grown, but with the exception of the specimens received from Olive, of South Dakota, E. Meade Wilcox, of Nebraska, and E. H. Smith,[15] of California, there was reported no evidence of the presence of the rust.

Fig. 9. Alfalfa rust, *Uromyces striatus*, branch bearing teleutospore sori.

ORIGIN OF THE RUST

It is difficult to account for the presence of the rust in Ames, as the alternate host on which it occurs has not been found near

the alfalfa. The alternate host has been thought to be the Cypress Spurge (*Euphorbia Cyparissias*), but Schroeter took the teleutospores from the red clover. It is probable that he was in error regarding the clover rust being the same as that upon alfalfa, for it seems probable, according to Kern, that there are several species of rust on clover. There is a possibility that an aecidium may occur on *Euphorbia Lathyris* which occurs not far distant from the alfalfa plants. The *E. commutata*, closely related to *E. Cyparissias*, does not occur in this vicinity. We are inclined to think that the aecidium occurs on an entirely different host plant, or that it was brought in with green alfalfa plants scattered along the right of way of the railroad.

CHARACTERS OF THE FUNGUS

The sori of the rust occur on both surfaces of the leaf, and upon the stem; color, cinnamon brown; shape, round or elongated. Uredo sori are produced throughout the summer, becoming abundant in August especially affecting older plants. The uredo spores are subglobose to elliptical, at first partially covered by epidermis which ruptures leaving the spores exposed; teleuto spores are 1-celled, ovate to elliptical or pyriform, 18-28μ by 14-20μ; apiculate, with longitudinal striations; pedicel short, nearly colorless.

Arthur [15a] records successful transfers of *U. striatus* to *Medicago sativa* in the greenhouse; uredo spores from resulting cultures infected alfalfa, but not *Trifolium pratense*, *T. medium* nor *T. repens*. We did not succeed in transferring it to red clover.

THE BLISTER CANKER OF THE APPLE OR ILLINOIS CANKER (*Nummularia discreta, Tul.*)

During the fall of 1910 the writer received a communication from Simons & Sons of Hamburg, Iowa, with reference to a serious canker that was particularly severe on the Ben Davis variety of apples, appearing in southwestern Iowa. Mr. Simons says in regard to the disease:

"In regard to the canker on the apple, we cannot say just when the disease appeared in our orchard. Ten or twelve years ago the writer rented an orchard that adjoins ours. At that time the Ben Davis on the place were nearly all affected and in fact nearly all used up by the canker. Did not know at that time what it was. Now all those Ben Davis are dead or nearly all of them but it is appearing on some of the young Ben Davis on the same place. The Jeniton, Wine Sap, and in few places Jonathan are affected. On our own original 30 acres, we have the most canker on the side next to this old orchard and the disease has

apparently spread from a tree that was injured by a run awy team. The Wine Sap, Missouri Pippin, and Jontathan, do not seem to be affected. We are inclined to think that we have spread the disease by pruning tools. Did not realize that we were doing so until a couple of years ago. Since then we have tried to be careful to disinfect tools after working on diseased trees. The disease appears to take effect where a bruise or cut has been made. So far we have not been successful in holding in check to any extent the cankered portions. We think we have not cut far enough back into the live bark in cutting out the disease. We do not know whether there are many orchards affected or not."

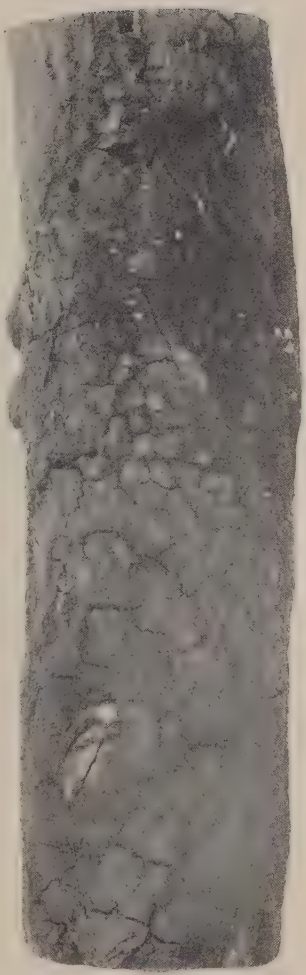

Fig. 10. Branch of apple, diseased by Illinois canker. Photo by F. E. Colburn.

We have had considerable correspondence with reference to several other canker diseases in different sections of the state. Some of these apparently are quite obscure as to their cause. In one type of canker there is a resemblance to injuries from hail and subsequently the diseased areas are covered over with new bark. The term canker has long been used to designate the irregular excrescences resulting from some injury with an effort on the part of the plant to heal over. Well-known illustrations of canker are those produced by the European canker caused by *Nectria ditissima*; the canker produced by *Dasyscypha Willkomii*; the canker of the bitter rot (*Glomerella rufomaculans*); the black rot canker of pomaceous fruit (*Sphaeropsis malorum*) or the New York apple tree canker; and the myxosporium canker (*Myxosporium corticolum*) or the macrophoma canker, referred to by Stewart.[15b]

Fig. 11. Section of Apple bough diseased by Illinois canker. Photo by F. E. Colburn.

The Illinois canker disease was carefully described by Hasselbring [16] and according to this author this fungus was not generally suspected of being troublesome as a disease, although Tulasne states that it occurs on the thick bark that has recently died. The fungus was collected by Schweinitz and described as *Sphaeria discreta.* According to Hasselbring the fungus is common in the apple growing regions of Illinois, as well as occurring in other parts of the state.

The disease may be characterized, briefly, as producing cankers upon the trunk and branches. The infected areas are blackened, slightly sunken, consisting of small spots of healthy tissue intermingled with the diseased area. These normal adjacent tissues usually die giving the canker a peculiar and characteristic appearance. The parasite may involve a considerable portion of the branch or trunk. The mycelium of the fungus occurs in the branch and later may be found in the wood underneath, even growing more rapidly in the wood than in the bark. The mycelium destroys the bark and causes a disintegration of the cells. The fruiting bodies of the fungus are developed during the latter

part of the summer, extending into the autumn and winter. The upper part of the stroma produces numerous erect threads which bear small bodies called conida. The conida are first covered by the bark and are not exposed until the rupture of the same. The conida are 1-celled, simple, hyaline; the underlying stromatic tissue which is club-shaped, develops flask-shaped perithecia which are sunken in the stroma; the lower portion of the perithecium is elliptical, becoming ovate at maturity, and is filled with long cylindrical asci measuring 150μx13μ. The asci are thick walled, provided with a terminal pore and contain at maturity eight more or less spherical brown spores 13μx 10μ. The ascospores have a clear space on one side through which the germ tube passes when germination occurs.

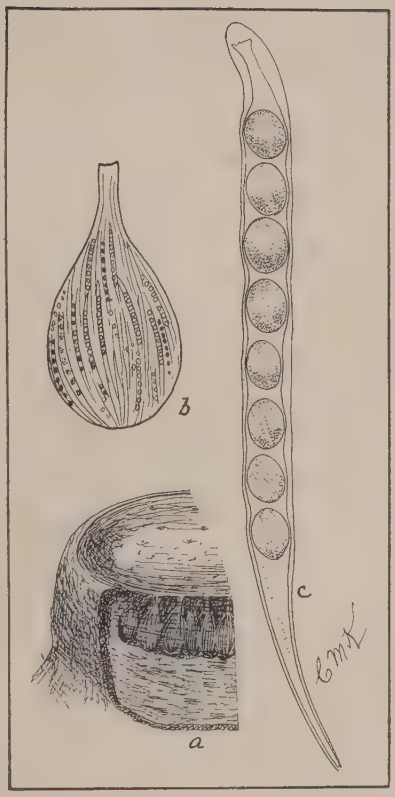

Fig. 12. NUMMULARIA DISCRETA
a, section of a stroma-bearing "blister"; b, flack shaped perithecium; c, ascus.

ONION SMUT (*Urocystis Cepulae* Frost)

Fig. 13. a, smutted onion; 1, smut; 2, *Aspergillus*; b, smutted onion (from Thaxter).

Early in the season of 1910 Leslie Hird called attention to the presence of onion smut in the onion growing section of eastern Iowa. He said that the losses resulting from the fungus were so great that the growers, in some cases, no longer found the crop profitable. This lead to inquiry into the matter. In the latter part of July, 1911, a visit was made to localities in Scott county, where the onion fields were found to be seriously affected by smut.

This disease was observed near Pleasant Valley, about the year 1900, by F. F. Schutter, an extensive onion grower of that region; other growers place the date as early as 1897, and 1899.

It seems that during the last five years the disease has spread rapidly, the smut probably being conveyed from field to field upon farm implements and with manure containing smutted onion refuse, as discarded onions are usually deposited upon manure piles. It was evident from examining the conditions of the plants in the summer that the yield would be seriously reduced

because of the presence of smut. This was confirmed at the end of the season.

A reliable report states that the average yield of fields treated with formalin was 200 bushels, this being less than half the average yield, while the yield of fields not treated was almost a total failure.

Dry weather was, of course, largely responsible for the meager crop, but smut disease was a significant contributing cause, the proportion of loss due to it being about 5 per cent in treated fields, and 10 to 50 per cent in untreated fields. In one untreated field the loss was estimated as 50 per cent.

Mr. Schutter kindly furnished this statement for 1910, a year when weather conditions were favorable: "The part treated yielded over 500 bu. per acre, and the untreated plot about 100 bu. of inferior onions per acre." This grower finds from his records that the average yield from 1898 to 1909 was 512 bushels per acre; the average receipts were 42.6c per bushel. About 300 acres of onions are grown in the region under consideration. A loss by smut of from 5 to 50% of the crop means to the region an annual loss of a good many thousand dollars.

This disease has long been known as troublesome in New England, particularly in Connecticut since 1865, according to Thaxter.[17] It was reported from Massachusetts by Ware [18] for 1869-70. The fungus was named *Urocystis Cepulae* by C. C. Frost, who communicated the name to Farlow. The first description of it was made by Farlow.[19] Subsequently Farlow [20] referred the *U. magica* found on a wild onion in Italy to the same species and Cooke referred the smut on the onion to *Urocystis Colchici var. Cepulae*. Later this true onion smut was found near Paris on onion and Cornu thought it was introduced from the United States. Thaxter gives a full account of the occurrence of the fungus in Europe and concludes that it is probably indigenous to that country. The *U. Cepulae* is distinct from the two European smuts *U. magica* and *U. Colchici*, the former occurring on a species of Wild Onion and the latter on *Colchicum* and Solomon's Seal (*Polygonatum*). Clinton in his monograph of North American Ustilagineae regards the species as distinct from the *U. Colchici*. Apparently it has not proven a very serious parasite in Europe as indicated by Lindau.[21] Clinton reports it from Vermont, Connecticut, Massachusetts, New Jersey, New York, Ohio, and on a native species of onion from Nevada. Stevens [22] and Hall report it from Georgia.

CHARACTERS OF THE FUNGUS

The disease is first indicated by several dark spots on the leaves of seedlings, which are readily seen when held up to the light; later the pustules show. These are, at first, covered by a membrane, which breaks and exposes the spores which are black-

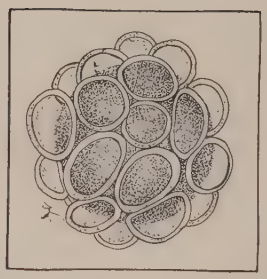

Fig. 14. Spore of *Urocystis Cepulae.*

ish. The affected leaf soon dies. If the plant is able to survive, pustules develop on other leaves and even on the bulbs where it occurs on the outer scales; sometimes the fleshy scales of the mature onion are discolored. The spores occur in clusters or spore balls. These spore balls are ovoid to spherical. There are two kinds of cells; the outer sterile are usually $4\mu x8\mu$ in length, the inner and fertile are reddish brown, ovoid to spherical, usually 1 or sometimes 2 in the spore ball, 12μ-16μ in length.*

This disease has become so severe that cultural methods have had to be materially changed. Thaxter stated:

"The severity of the disease in different localities is variable. It appears at first in isolated spots here and there in a field, and from these spreads in all directions until the whole piece becomes affected, and the cultivation of onions upon it has to be discontinued. This period from the first appearance of the smut to the enforced discontinuance of the onion crop, appears to be, on new ground, never less than five years, which is the shortest ascertained interval."

This seems, also, to have been the experience with the growers in eastern Iowa.

Short rotations do not materially diminish the amount of smut; in a particular field badly smutted the order of planting had been clover for two years, corn one year; a five year rotation will not, from the experience of growers, eliminate the disease. This also accords with the experience of growers in eastern Iowa.

HOW THE DISEASE IS SPREAD

It appears reasonably certain that the disease is not generally spread by the seed. A quantity of seed from the infected region was received of which a portion was washed, and the washings centrifuged. There was no evidence of presence of smut spores upon the seeds.

Checks to which smut spores had been added, when treated in the manner described above, always showed presence of the fungus.

The disease may, however, occasionally be introduced with seed from an infected locality. It is also certain that the disease is

* The onion smut sent us from Pleasant Valley, Iowa, had an abundance of a black mould (*Aspergillus niger*). Farlow to whom the specimen was submitted states that he also found this common on onions many years ago in Massachusetts.

spread with agricultural implements, as the plow, harrow, weeders, rakes, and hoes, by smut spores clinging with infected earth, to the implements.

A particular case was cited to us where smut first appeared in Scott county when a grower spread it from an infected field with implements used in cultivation.

It may also be transmitted by earth carried by man, and by farm animals. Water readily carries smut, or dust blown from an infected field may be the means of communicating the disease. Insects may also carry smut spores. Smutted onions, unfit for market, are often deposited with refuse upon manure piles, and are distributed over the fields.

VITALITY OF SPORES

It appears from the investigations of Thaxter that the spores may retain their vitality for a long period of time. He found an abundance of smutted onion plants in a field after a lapse of twelve years from previous planting with onions. Four or five years he thinks is wholly insufficient to eradicate the disease.

TREATMENT

An effective remedy for the disease is to transplant onion sets grown in a bed of soil free from the disease. This is, of course, a laborious process. This method has been recommended by W. C. Sturgis.[23] It has been successfully tried in Scott county. Selby also reports on the resistance of onion sets, or seedling onions grown in soil free from the disease; the fungus can enter only the very young onions.

Selby [24] recommends formalin, 1 pound to 25-33 gallons of water, and applied with a drip attachment on a seed drill at the rate of 500 to 700 gallons of the solution to an acre. Sirrine and Stewart [25] recommend the lime sulphur treatment whenever the loss from smut is as much as one-third of the crop. The sulphur and lime should be applied in drills. Lime and sulphur appear to have no effect on the smut when sown broadcast. Stevens & Hall recommend the following measures: Where soil is known to be infected, one pound 40% formaldehyde to 25-33 gallons of water, should be applied with a drip attachment on a seed drill, at rate of 500 to 700 gallons of solution for each acre.

This method has been used for 6 years by Mr. Schutter with successful results. Apparently where onions are drilled in with formalin treatment after the rain, there was less smut in the field than when drilled in just previous to a rain. The late treated onions seemed in less serious condition than the earlier treated onions; treatment in the morning seemed more effective than when made in the afternoon.

For proper treatment the soil should be in excellent condition;

if it is not friable and in a good state of tilth it is more difficult to treat, and results are correspondingly less effective. Occasionally the drip does not work well, and the amount of smutted onions is correspondingly great in such rows. Some of the planters use one pound of formaldehyde 40% solution to 15 to 20 gallons of water; but it is not more effective in the resulting crop than the weaker solution. The U. S. Department of Agriculture has successfully treated onions for onion smut by applying the formalin with a sprinkler in an open furrow until the seeds are well moistened. This method destroys the fungus in adjacent soil particles. Material gains by use of this method have been reported, both by the U. S. Department of Agriculture and by Selby.

We have made some tests of the effect of formalin in different strengths upon the germination of onion seeds. The test resulted as follows: in water 63% of the onion seeds germinated; in ¼% solution, 66%; in ½% solution, 62%; 2% solution gave 15%; 5% solution, 29% and 8% solution gave a germination of 1%. The presence of a very slight amount of formaldehyde seemed to stimulate germination while stronger solutions were detrimental.

Ground quick lime, 75 to 125 bushels per acre, on the freshly prepared soil, just before seeding, has been found useful. It appears from the results of the work carried on near Pleasant Valley that this helps somewhat but by no means destroys the fungus, and is not so effective as the formaldehyde treatment. Rotation of crops, except over very long periods, cannot be depended upon.

The main point to be observed by growers of onions is to select a non-infected soil. When it is the intention to raise onions, care should be used with reference to implements that have been used in infected areas, and that no animal be taken from an infected area to a non-infected area. The onion grower can afford to run no risk.

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